Physics 203 – Principles of Physics III
Homework Chapter 20
Assignment #3
February 26, 2008

20-13: a) $W = |Q_H| - |Q_C| = 550\,\text{J} - 335\,\text{J} = 215\,\text{J}.$

b) $T_C = T_H \dfrac{|Q_C|}{|Q_H|} = (620\,\text{K})\dfrac{335\,\text{J}}{550\,\text{J}} = 378\,\text{K}.$

c) $\varepsilon = 1 - (|Q_C|/|Q_H|) = 1 - (335\,\text{J}/550\,\text{J}) = 39\%.$

20-16: a) For a Carnot engine $\dfrac{|Q_C|}{|Q_H|} = \dfrac{T_C}{T_H}$, thus $Q_H = \left(\dfrac{320\,\text{K}}{270\,\text{K}}\right)(415\,\text{J}) = 492\ \text{J}.$

b) The work per cycle is 492 J – 415 J = 77 J, and

$P = \dfrac{165\,\text{cycles}}{60\,\text{sec}} \dfrac{77\,\text{J}}{1.00\,\text{s}} = 212$ W, keeping an extra figure.

c) $T_C/(T_H - T_C) = (270\text{ K})/(50\text{ K}) = 5.4.$

20-22: For an isothermal compression, $\Delta T = 0$, $\Delta U = 0$ and $Q = W$. The change of entropy is $\Delta S = \dfrac{Q}{T} = \dfrac{-1850\,J}{293.15\,K} = -6.31\ J/K.$

20-28: a) $\Delta S = \dfrac{Q}{T} = \dfrac{mL_v}{T} = \dfrac{(1.00\,kg)(2256x10^3\ J/kg)}{(373.15\ K)} = 6.05x10^3\ \ J/K.$ Note that this is the change of entropy of the water as it changes to steam.

b) The magnitude of the entropy change is roughly five times the value found in Example 18-5 for ice converted into water. Water is less ordered (more random) than ice, but water is far less random than steam; a consideration of the density changes indicates why this should be so.

20.46: a) $p_2 = p_1 = 2.00\ \text{atm},$

$V_2 = V_1 \frac{T_2}{T_1} = (4.00\,\text{L})(3/2) = 6.00\,\text{L}.\ V_3 = V_2 = 6.00\,\text{L},$

$p_3 = p_2 \frac{T_3}{T_2} = p_2(5/9) = 1.111\,\text{atm},$

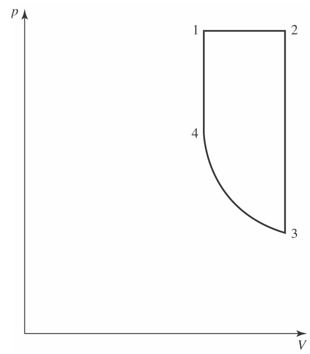
$p_4 = p_3 \frac{V_3}{V_4} = p_3(3/2) = 1.67\,\text{atm}.$

As a check, $p_1 = p_4 \frac{T_1}{T_4} = p_4(6/5) = 2.00\ \text{atm}.$

To summarize,

$(p_1, V_1) = (2.00\text{ atm, }4.00\text{ L})$ $\qquad (p_2, V_2) = (2.00\text{ atm, }6.00\text{ L})$

$(p_3, V_3) = (1.111\text{ atm, }6.00\text{ L})$ $\qquad (p_4, V_4) = (1.67\text{ atm, }4.00\text{ L}).$



b) The number of moles of oxygen is $n = \frac{p_1 V_1}{RT_1}$, and the heat capacities are those in Table (19.1) on page 740. The product $p_1 V_1$ has the value $x = 810.4\ \text{J}$; using this and the ideal gas law,

$$\text{i}: \quad Q = nC_P \Delta T = \frac{C_P}{R} x \left(\frac{T_2}{T_1} - 1 \right) = (3.508)(810.4\ \text{J})(1/2) = 1422\ \text{J},$$

$$W = p_1 \Delta V = x \left(\frac{T_2}{T_1} - 1 \right) = (810.4\ \text{J})(1/2) = 405\ \text{J}.$$

$$\text{ii}: \quad Q = nC_V \Delta T = \frac{C_V}{R} x \left(\frac{T_3 - T_2}{T_1} \right) = (2.508)(810.4\ \text{J})(-2/3) = -1355\ \text{J, W} = 0.$$

$$\text{iii}: \quad W = nRT_3 \ln\left(\frac{V_4}{V_3} \right) = x \frac{T_3}{T_1} \ln\left(\frac{V_4}{V_3} \right) = (810.4\ \text{J})(5/6) \ln(2/3) = -274\ \text{J},\ Q = W$$

$$\text{iv}: \quad Q = nC_V \Delta T = \frac{C_V}{R} x \left(1 - \frac{T_4}{T_1} \right) = (2.508)(810.4\ \text{J})(1/6) = 339\ \text{J, W} = 0.$$

In the above, the terms are given to nearest integer number of joules to reduce roundoff error.

c) The net work done in the cycle is $405\ \text{J} - 274\ \text{J} = 131\ \text{J}$.

d) Heat is added in steps i and iv, and the added heat is $1422\ \text{J} + 339\ \text{J} = 1761\ \text{J}$ and the efficiency is $\frac{131\ \text{J}}{1761\ \text{J}} = 0.075$, or 7.5%. The efficiency of a Carnot-cycle engine operating between $250\ \text{K}$ and $450\ \text{K}$ is $1 - \frac{250}{450} = 0.44 = 44\%$.